Numerical simulation of heavy metal (Copper) in the Oujiang Estuary

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ABSTRACT

A three-dimensional model of heavy metal transport was applied to simulate the copper content of the Oujiang Estuary. The modeled processes included not only the convection and diffusion of heavy metals in the water column, but also sediment-associated processes such as erosion and deposition of sediments, adsorption and desorption, and pore water diffusion and advection. The model was calibrated using measured data for water surface elevation, flow velocity, suspended sediment concentration, the proportion of copper sorbed in sediment, and the dissolved copper concentration. Meanwhile, the temporal and spatial variability of the suspended sediment, together with dissolved, particulate and total copper were analyzed.

KEY WORDS: Numerical model; heavy metal transport; sediment; copper; Oujiang estuary.

INTRODUCTION

Estuary serves as a meeting point between land and sea, and has occupied considerable importance: to conservation groups (e.g. for their flora and fauna), to industrialists (e.g. for their sheltered access to coastal waters for shipping) and to local communities (e.g. for recreation and for efficient and high dispersion of effluent waste) (Falconer and Lin, 1997).

Therefore, in recent years there has been a marked increasing awareness of aqua-environmental and heavy metal pollution in estuarine waters. In addition to coastal aquaculture, another of the main reasons for this growing awareness is as a result of increased leisure time and recreation, and the corresponding increase in the use of estuarine waters for such leisure activities.

In assisting engineers and scientists in evaluating the environmental impact of potential pollution sources on estuarine receiving waters, field measurement has historically been used. However, this method could provide continuous time-series data at a point detailed temporal, but not spatial resolution (David et al., 2007). Thus, engineers and scientists have increasingly turned to numerical models for such study (Grenney et al., 1978; Wool et al., 2001; Hamrick et al., 2002). Numerical models are less costly and more easily employed tools, and could give the temporal and spatial data (Schoellhamer et al., 2007; Wencheng et al., 2007)

In numerically modelling the heavy metal transport, the influence of sediment on the heavy metal transport need be considered. And the impact of sediment can be briefly described as follows: Heavy metal may adsorb to suspended sediment particles and desorb from sediment particles to water (Chao et al., 2010). In addition, the contaminants adsorbed to suspended sediments may be transported into or out of the bed with sediment erosion and deposition. The contaminants adsorbed to bottom sediments may be released back into the surface water column through pore water diffusion and advection (Ruijie et al., 2012).

In this paper, a three-dimensional model was described and applied in the Oujiang estuary. The flow, suspended sediment and heavy metal transport process are modeled and reproduced, and the modelled results including the temporal and spatial variability of the suspended sediment, together with the dissolved, particulate and total copper were analyzed. The results could give some assist for scientists and engineers in heavy metal transport modelling and sea use planning.

DESCRIPTION OF THE MODEL

Hydrodynamic Model

We used the Environmental Fluid Dynamics Code (EFDC) hydrodynamic model, which incorporates momentum equations and the continuity equation; details can be found in Hamrick (2002). Solving the hydrodynamic equations yields water surface elevations and longitudinal and vertical velocities, which are input into the sediment and heavy metal transport simulations.

Sediment Transport Model

The EFDC model’s sediment transport component was also used (Hamrick, 2002). The governing equation for 3-dimensional sediment transport is:

\[
\frac{\partial \varepsilon_s}{\partial t} + \frac{\partial \varepsilon_{sx}}{\partial x} + \frac{\partial \varepsilon_{sy}}{\partial y} + \frac{\partial (w - \omega_z) \varepsilon_s}{\partial z} =
\]

\[
\frac{\partial}{\partial x} \left( \varepsilon_{sx} \frac{\partial \varepsilon_s}{\partial x} \right) + \frac{\partial}{\partial y} \left( \varepsilon_{sy} \frac{\partial \varepsilon_s}{\partial y} \right) + \frac{\partial}{\partial z} \left( \varepsilon_{sz} \frac{\partial \varepsilon_s}{\partial z} \right)
\]

where \( s \) is the suspended sediment concentration (mg/L), \( t \) is the elapsed time (s), \( u \) and \( v \) are the horizontal velocity components of the dimensionless curvilinear–orthogonal horizontal coordinates \( x \) and \( y \)